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(54) **FIELD EMISSION CATHODE DEVICE AND FIELD EMISSION EQUIPMENT USING THE SAME**

(71) Applicants: **Tsinghua University**, Beijing (CN); **HON HAI PRECISION INDUSTRY CO., LTD.**, New Taipei (TW)

(72) Inventors: **Peng Liu**, Beijing (CN); **Chun-Hai Zhang**, Beijing (CN); **Duan-Liang Zhou**, Beijing (CN); **Bing-Chu Du**, Beijing (CN); **Cai-Lin Guo**, Beijing (CN); **Pi-Jin Chen**, Beijing (CN); **Shou-Shan Fan**, Beijing (CN)

(73) Assignees: **Tsinghua University**, Beijing (CN); **HON HAI PRECISION INDUSTRY CO., LTD.**, New Taipei (TW)

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CPC ***H01J 1/304*** (2013.01); ***H01J 3/021*** (2013.01); ***H01J 31/127*** (2013.01); *H01J 2203/0236* (2013.01)

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USPC 313/346, 495–497
See application file for complete search history.

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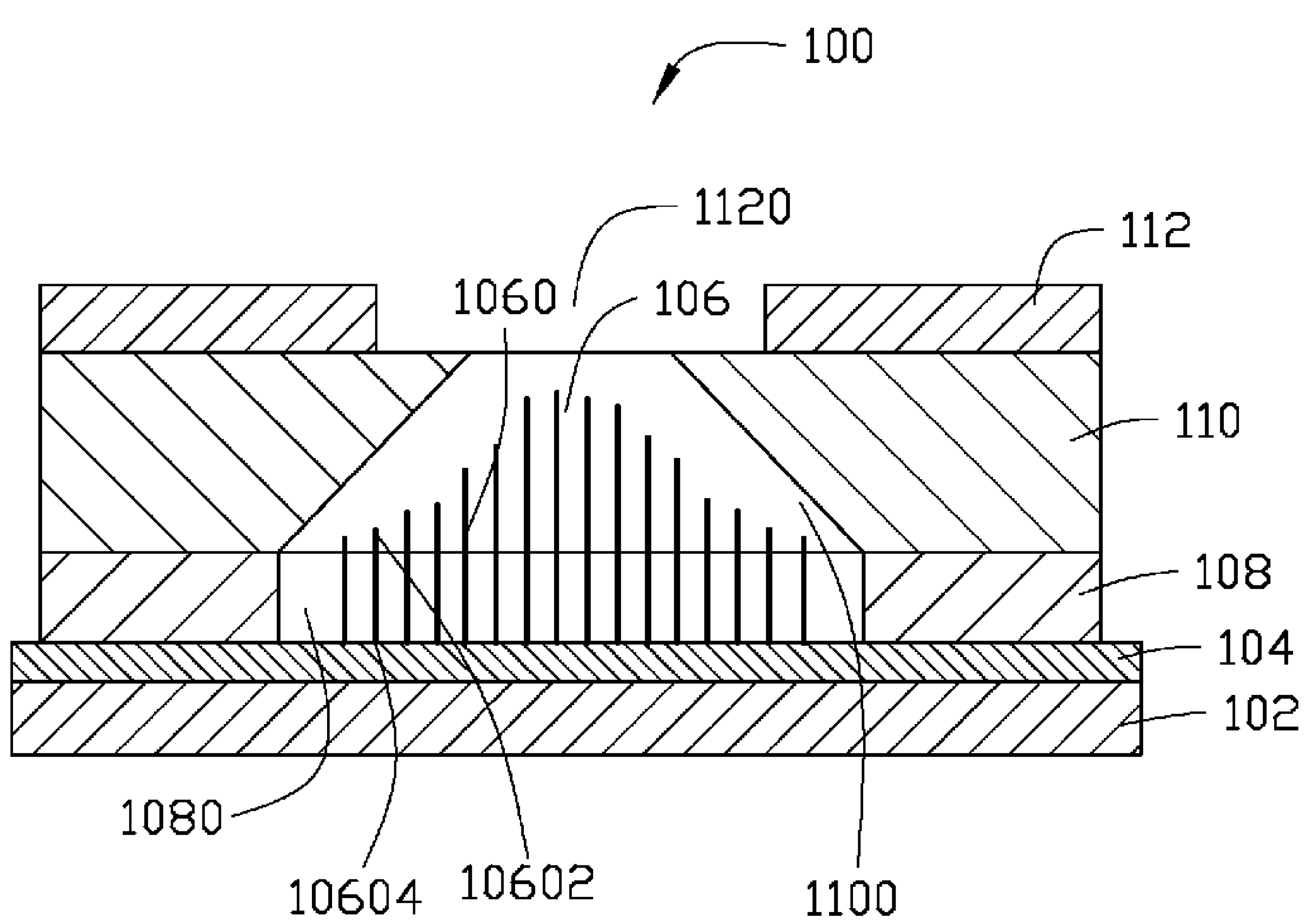
Primary Examiner — Thomas A Hollweg
(74) *Attorney, Agent, or Firm* — Novak Druce Connolly Bove + Quigg LLP

(57) **ABSTRACT**

A field emission cathode device includes a cathode electrode. An electron emitter is electrically connected to the cathode electrode, wherein the electron emitter includes a number of sub-electron emitters. An electron extracting electrode is spaced from the cathode electrode by a dielectric layer, wherein the electron extracting electrode defines a through-hole. The distances between an end of each of the sub-electron emitters away from the cathode electrode and a sidewall of the through-hole are substantially equal.

18 Claims, 12 Drawing Sheets



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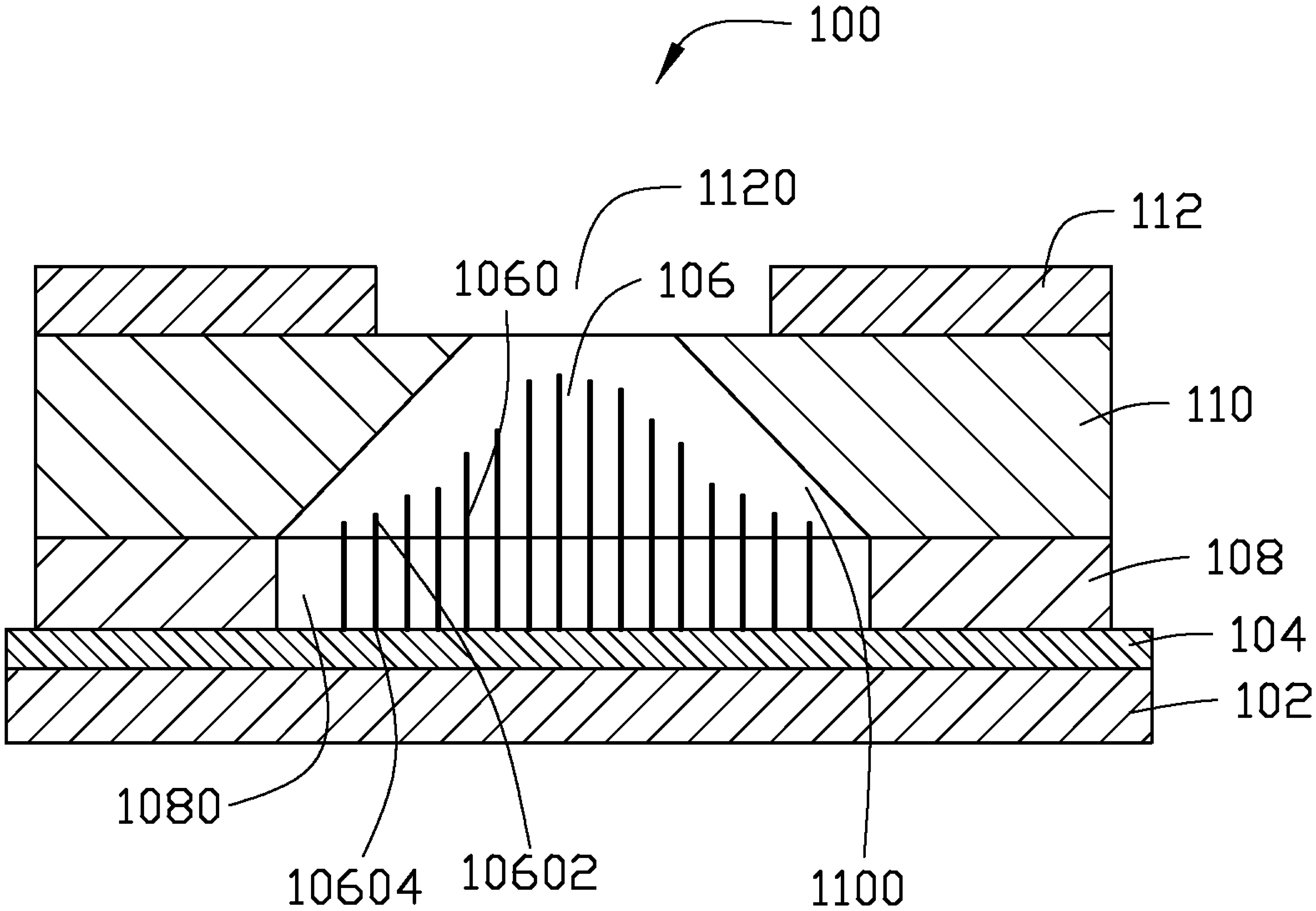

FIG. 1

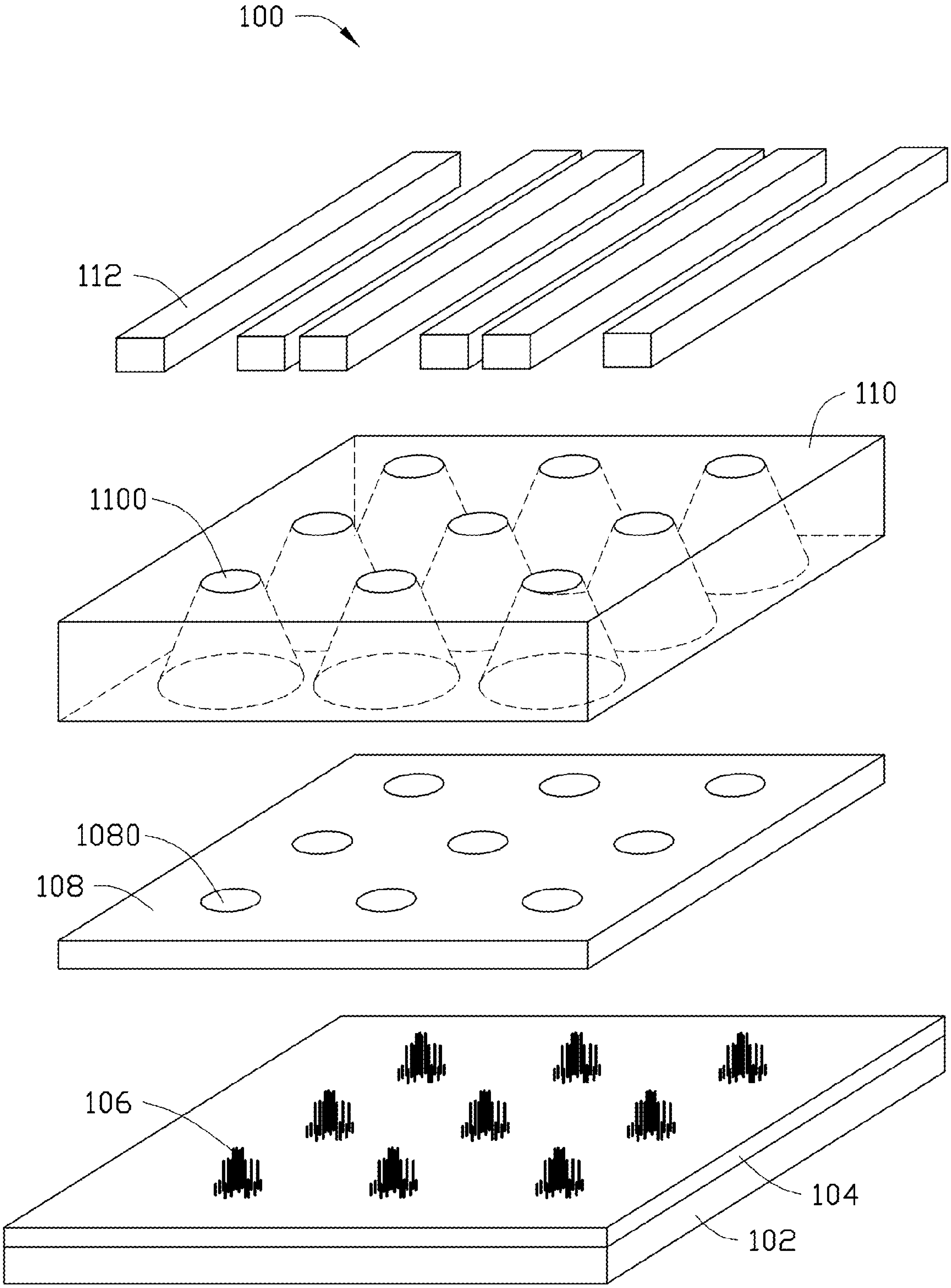

FIG. 2

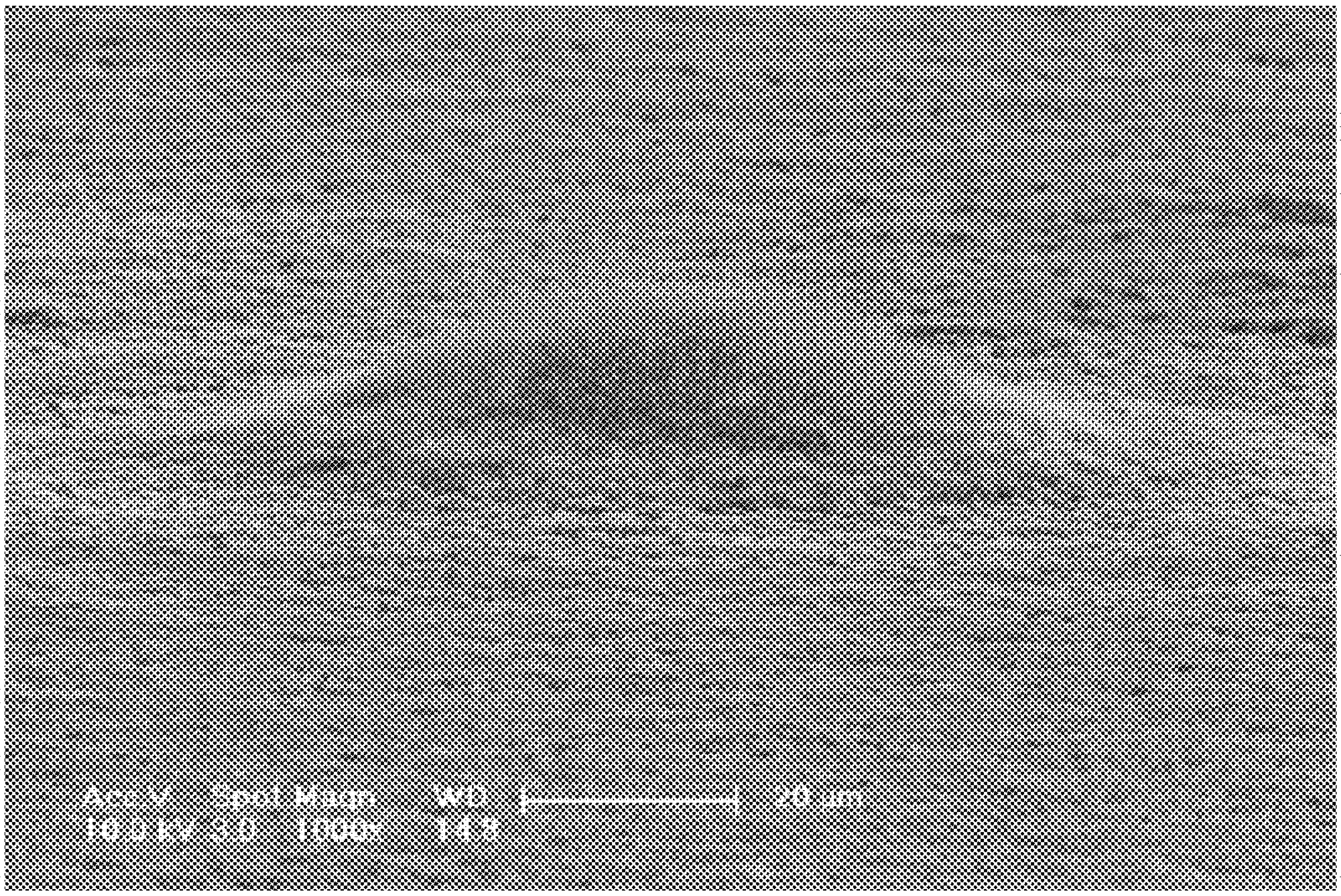

FIG. 3

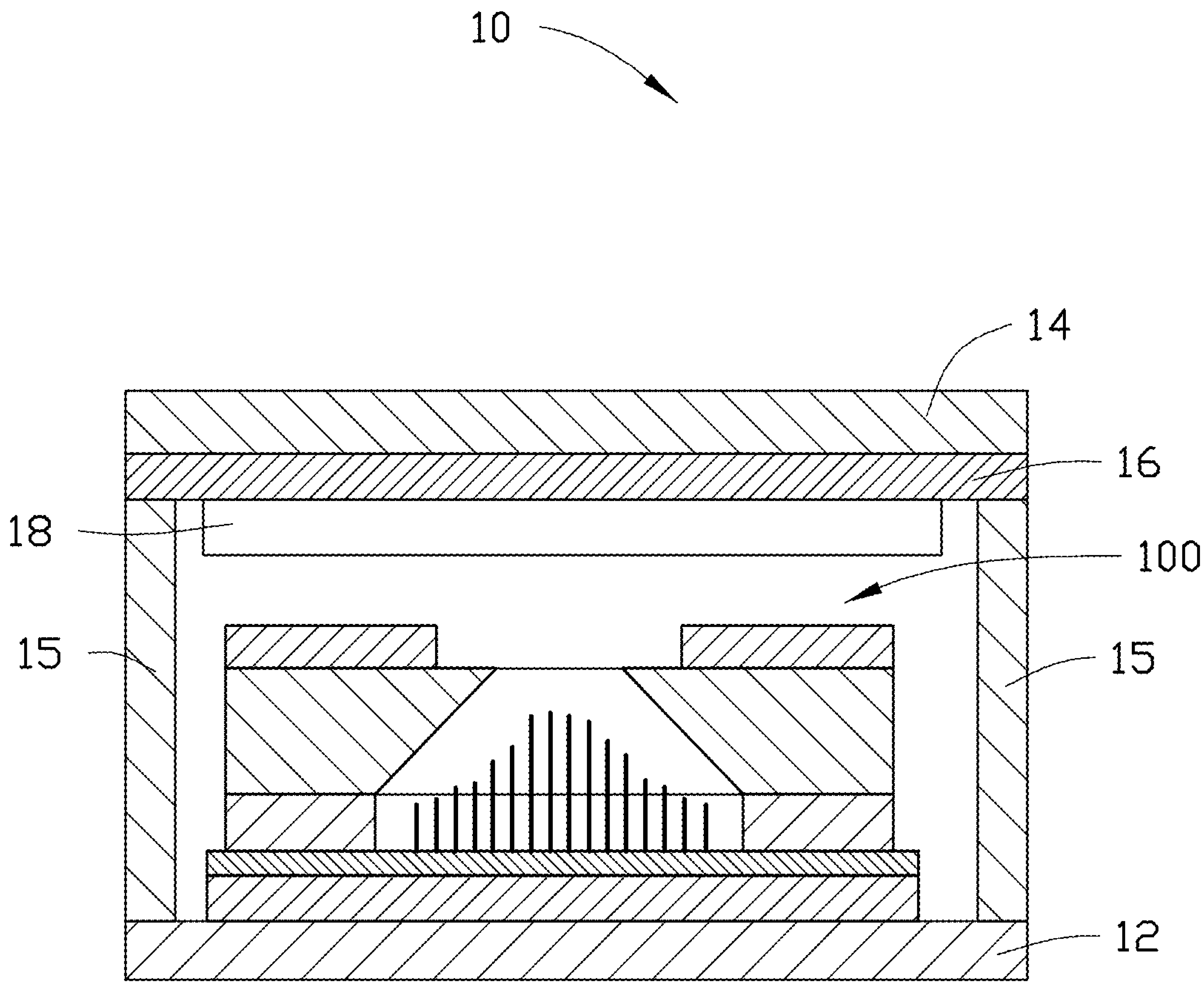

FIG. 4

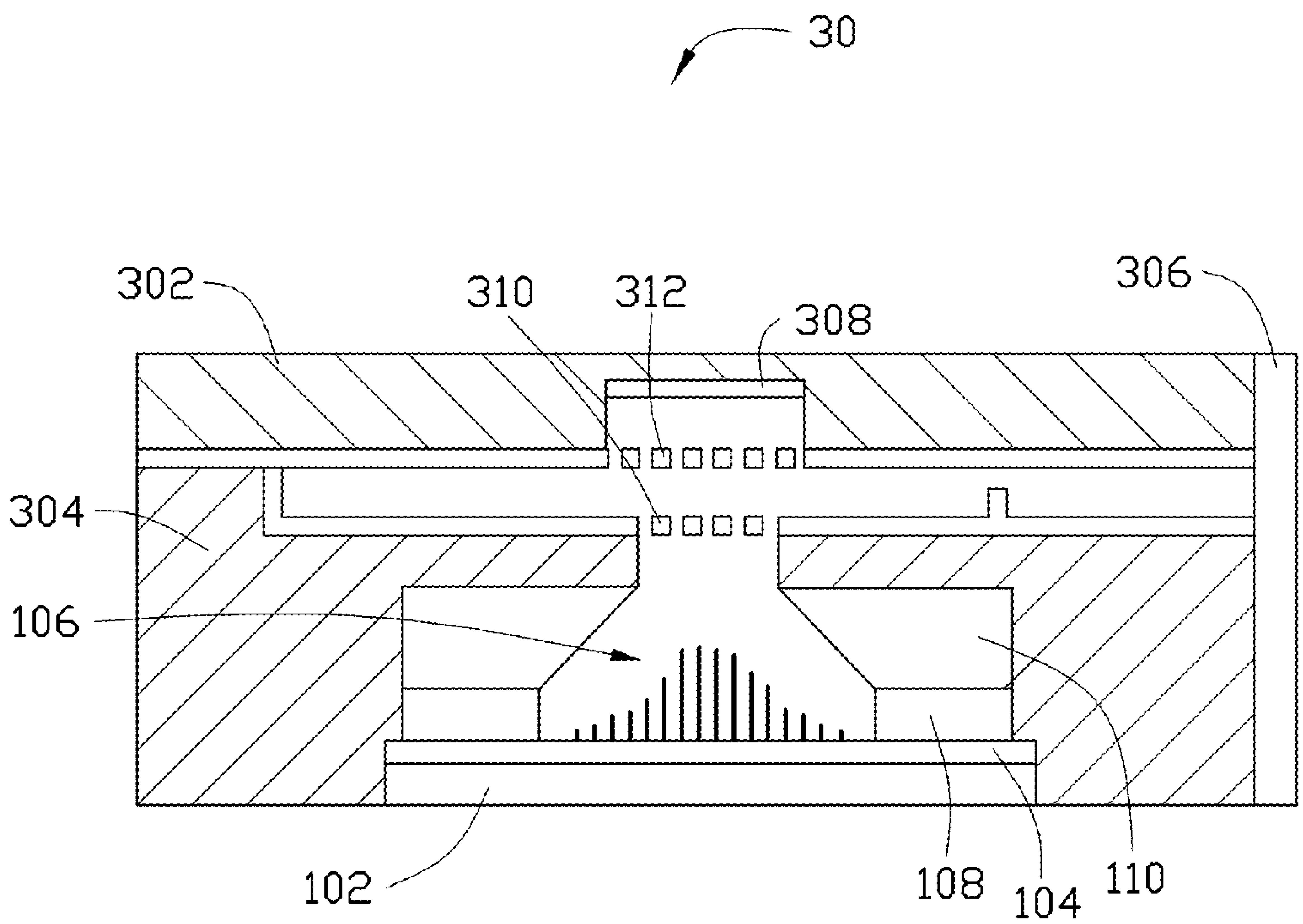

FIG. 5

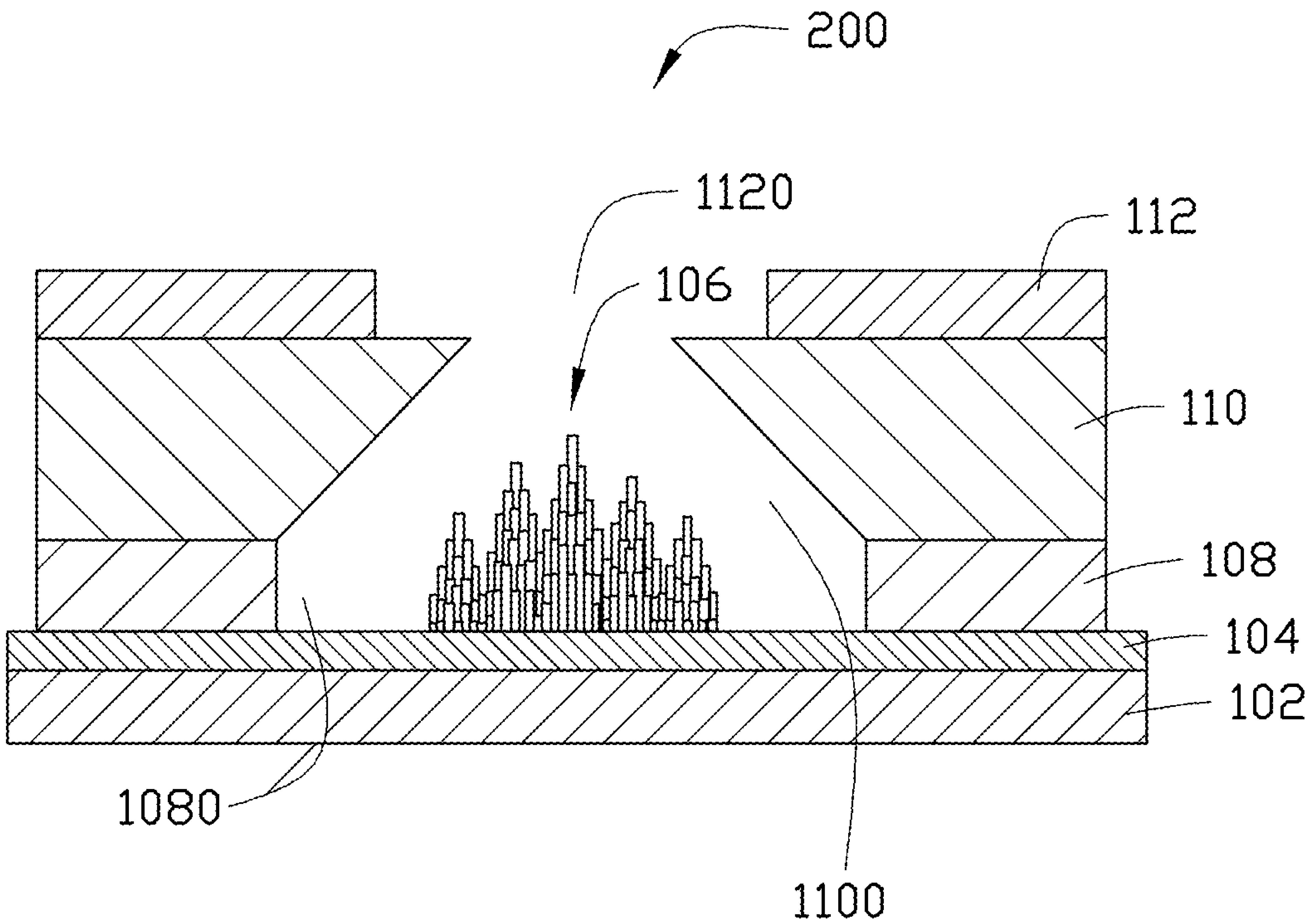

FIG. 6

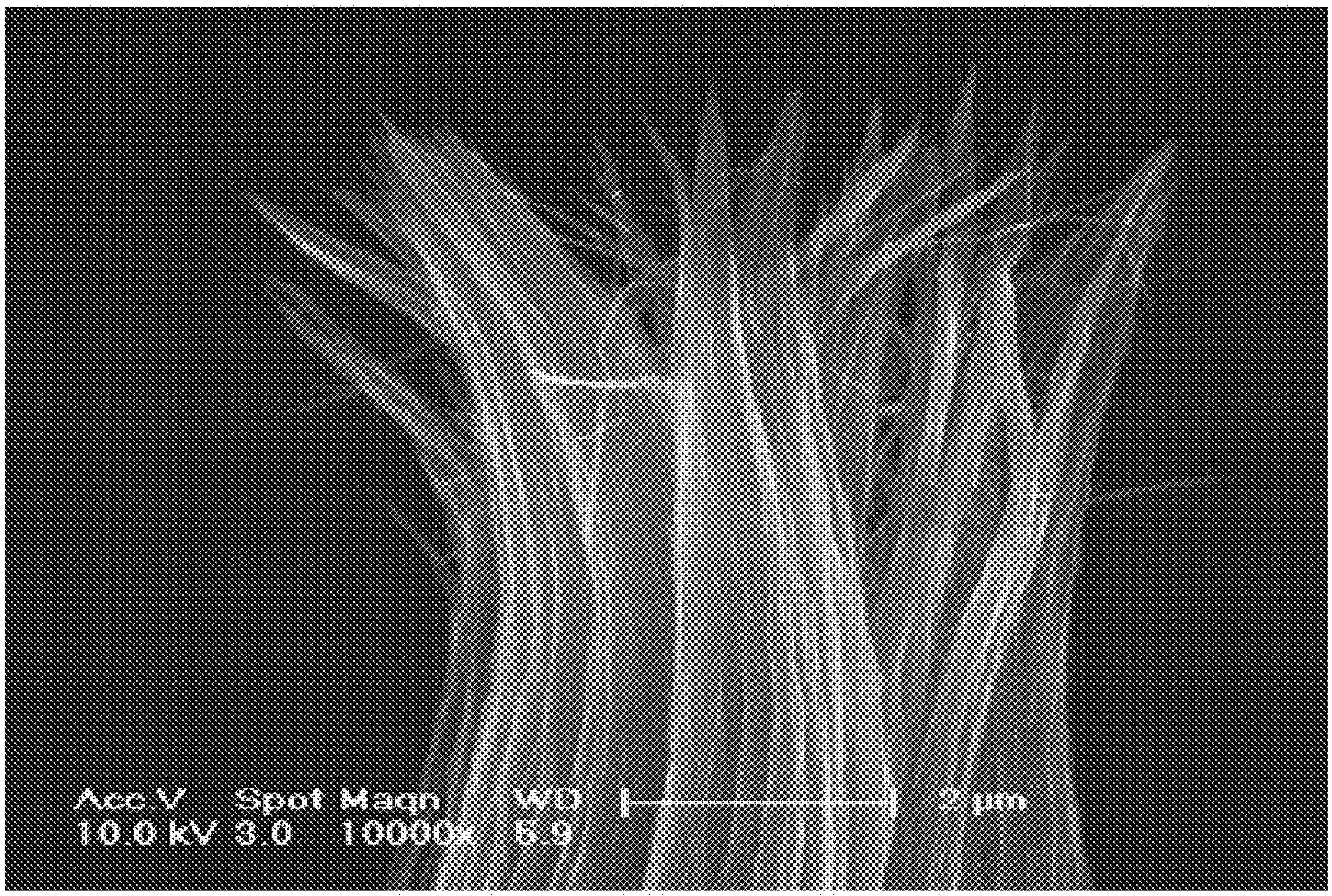

FIG. 7

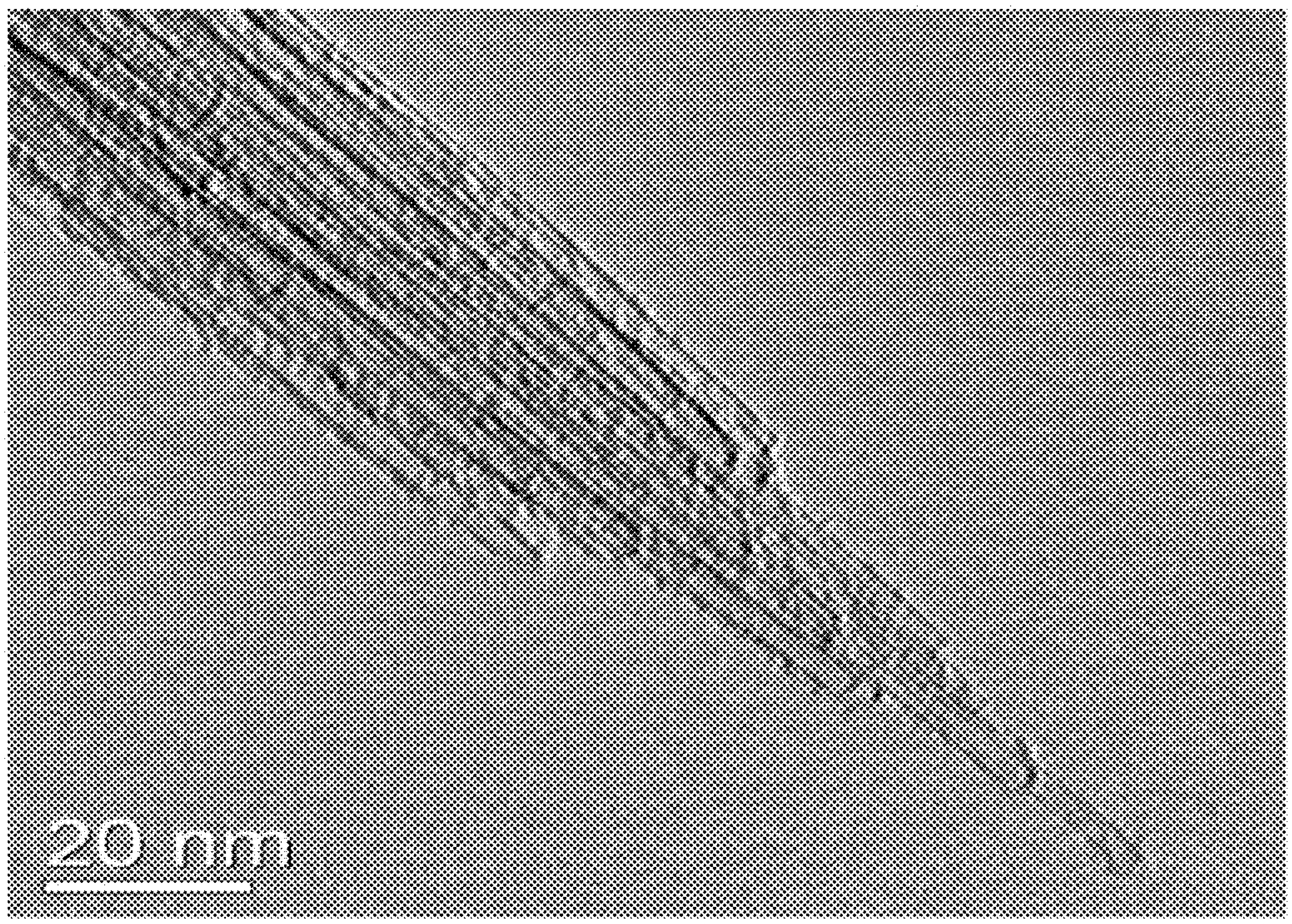

FIG. 8

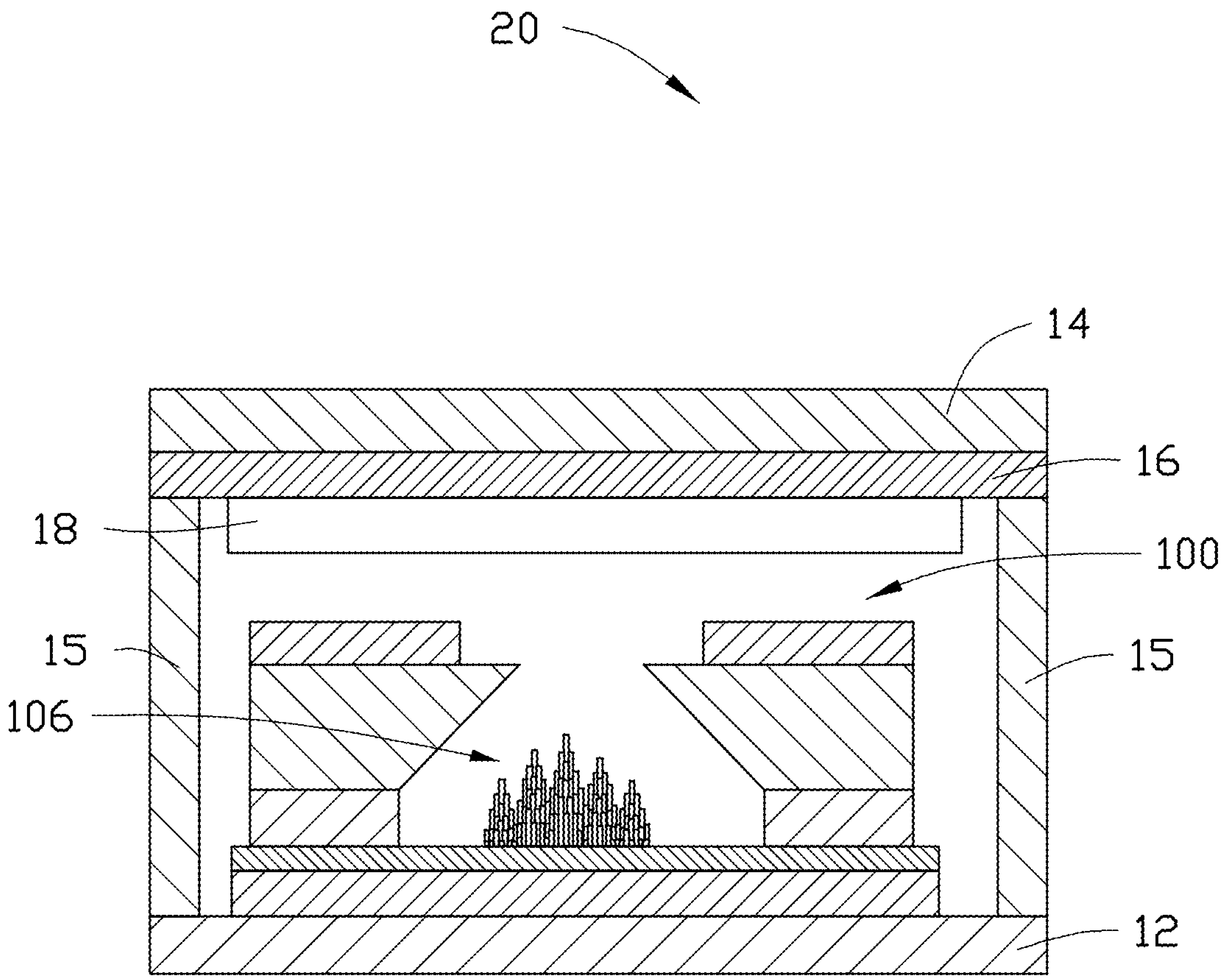

FIG. 9

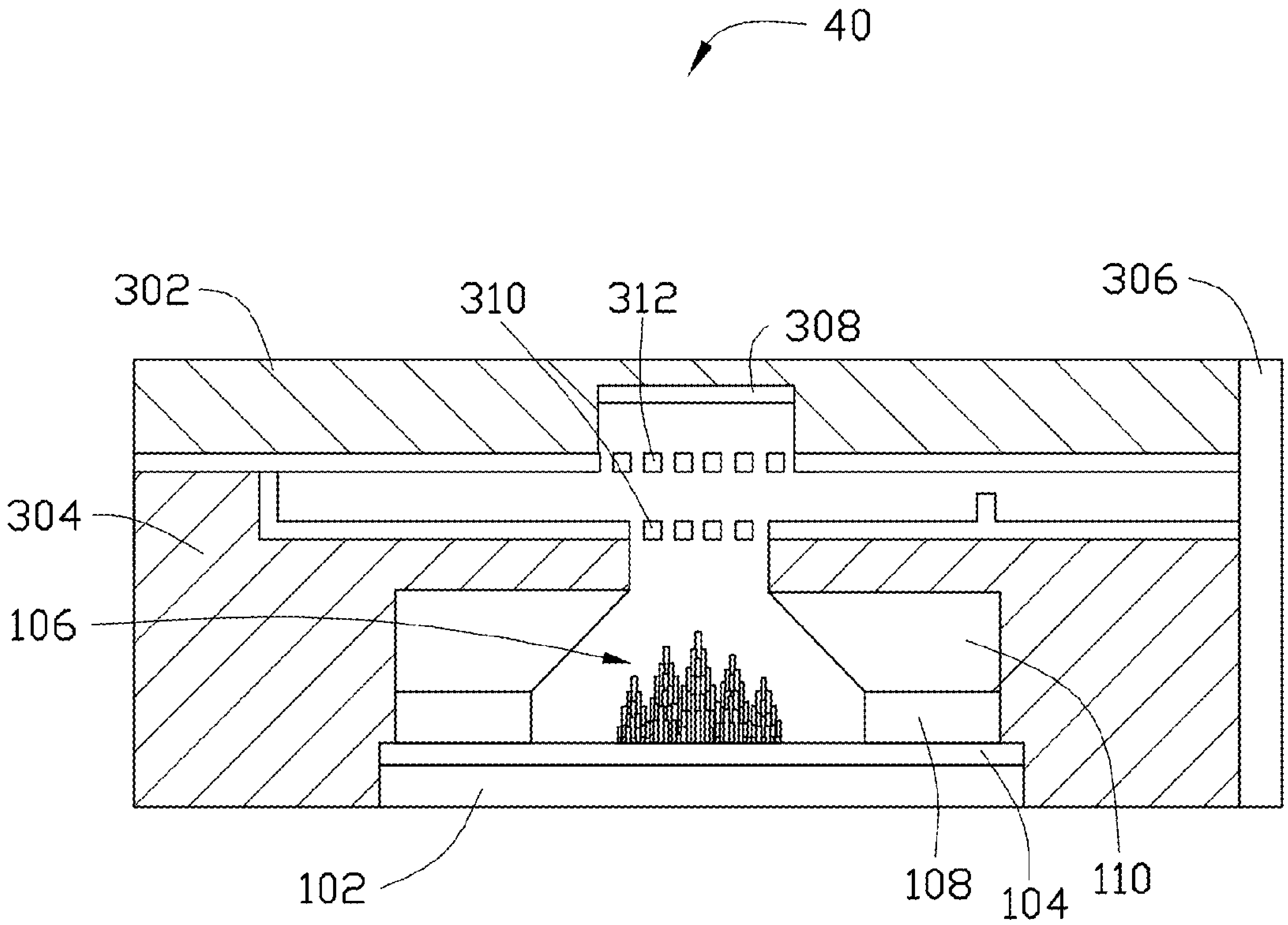

FIG. 10

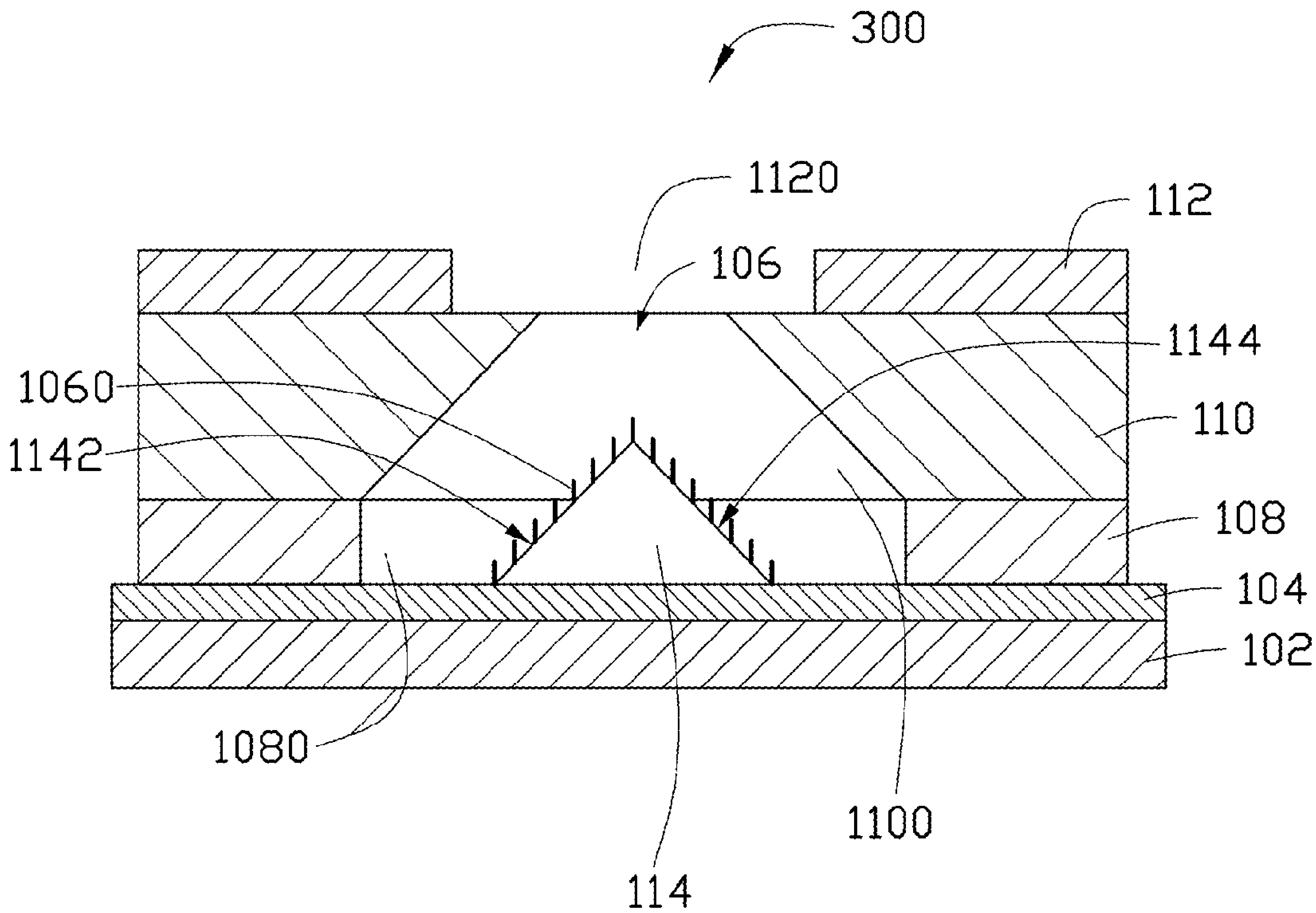

FIG. 11

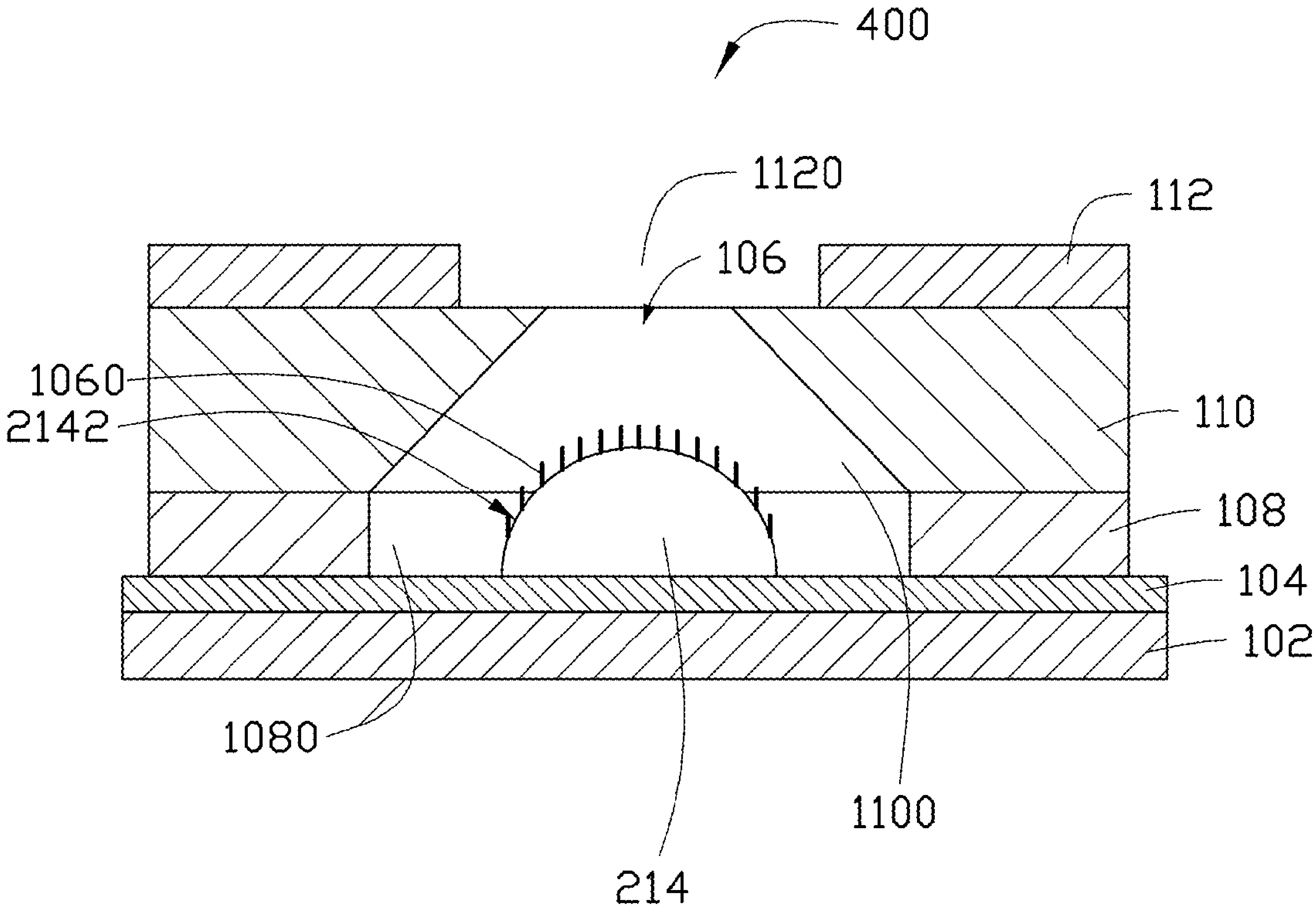

FIG. 12

FIELD EMISSION CATHODE DEVICE AND FIELD EMISSION EQUIPMENT USING THE SAME

RELATED APPLICATIONS

This application claims all benefits accruing under 35 U.S.C. §119 from China Patent Application No. 201210518136.2, filed on Dec. 6, 2012 in the China Intellectual Property Office, the disclosure of which is incorporated herein by reference.

BACKGROUND

1. Technical Field

The present application relates to a field emission cathode device and field emission equipment using the field emission cathode device.

2. Discussion of Related Art

Conventional field emission cathode device includes an insulating substrate, a cathode electrode fixed on the insulating substrate, a plurality of electron emitters fixed on the cathode electrode, a dielectric layer fixed on the insulating substrate, and a gate electrode fixed on the dielectric layer. The gate electrode provides an electrical potential to extract electrons from the plurality of electron emitters. When a field emission display using the field emission cathode device is operated, an anode electrode provides an electrical potential to accelerate the extracted electrons to bombard the anode electrode for luminance.

However, the electron emitters such as carbon nanotubes, carbon nanofibres, or silicon nanowires have equal length. The electron emitters close to the gate electrode have large field strength, and the electron emitters away from the gate electrode have very small field strength. Therefore, the electron emitters close to the gate electrode can emit more electrons, the electron emitters away from the gate electrode can emit very few electron, which affects the emission current of the electron emitters.

What is needed, therefore, is to provide a field emission cathode device and field emission equipment using the field emission cathode device to overcome the afore mentioned shortcomings.

BRIEF DESCRIPTION OF THE DRAWINGS

Many aspects of the embodiments can be better understood with references to the following drawings. The components in the drawings are not necessarily drawn to scale, the emphasis instead being placed upon clearly illustrating the principles of the embodiments. Moreover, in the drawings, like reference numerals designate corresponding parts throughout the several views.

FIG. **1** is a schematic view of one embodiment of a field emission cathode device.

FIG. **2** is a three-dimensional exploded schematic view of one embodiment of the field emission cathode device array.

FIG. **3** is scanning electron microscope (SEM) image of a carbon nanotube array.

FIG. **4** is a schematic view of one embodiment of a pixel unit of a field emission display.

FIG. **5** is a schematic view of one embodiment of a THz electromagnetic tube.

FIG. **6** is a schematic view of another embodiment of a field emission cathode device.

FIG. **7** is a SEM image of a carbon nanotube linear structure.

FIG. **8** is a transmission electron microscope (TEM) image of an end portion of the carbon nanotube linear structure of FIG. **7**.

FIG. **9** is a schematic view of another embodiment of a pixel unit of a field emission display.

FIG. **10** is a schematic view of another embodiment of a THz electromagnetic tube.

FIG. **11** is a schematic view of yet another embodiment of a field emission cathode device.

FIG. **12** is a schematic view of yet another embodiment of a field emission cathode device.

DETAILED DESCRIPTION

The disclosure is illustrated by way of example and not by way of limitation in the figures of the accompanying drawings in which like references indicate similar elements. It should be noted that references to "an" or "one" embodiment in this disclosure are not necessarily to the same embodiment, and such references mean at least one.

Referring to FIGS. **1** and **2**, a field emission cathode device **100** of one embodiment includes an insulating substrate **102**, a cathode electrode **104**, an electron emitter **106**, a dielectric layer **108**, and an electron extracting electrode **110**.

The cathode electrode **104** is located on a surface of the insulating substrate **102**. The dielectric layer **108** is located on a surface of the cathode electrode **104**. The dielectric layer **108** defines a first opening **1080**, such that a part of the cathode electrode **104** is exposed. The electron emitter **106** is located on a surface of the cathode electrode **104** and electrically connected to the cathode electrode **104**, wherein the surface is exposed through the first opening **1080**.

The electron extracting electrode **110** is located on a surface of the dielectric layer **108**. The electron extracting electrode **110** is spaced from the cathode electrode **104** by the dielectric layer **108**. The electron extracting electrode **110** defines a through-hole **1100**, exposing the electron emitter **106**. In one embodiment, the through-hole **1100** of the electron extracting electrode **110** is upside of the electron emitter **106**. The field emission cathode device **100** further includes a fixing element **112** located on a surface of the electron extracting electrode **110**. The fixing element **112** is used to fix the electron extracting electrode **110** on the dielectric layer **108**.

The dielectric layer **108** can be directly located on the cathode electrode **104** or directly located on the insulating substrate **102**. The dielectric layer **108** is located between the cathode electrode **104** and the electron extracting electrode **110**, such that there is insulation between the cathode electrode **104** and the electron extracting electrode **110**. The dielectric layer **108** can be a layer structure having the first opening **1080**. The dielectric layer **108** can be a plurality of strip-shaped structures spaced from each other. A gap between two adjacent strip-shaped structures is the first opening **1080**.

A material of the insulating substrate **102** can be ceramics, glass, resins, quartz, or polymer. The size, shape, and thickness of the insulating substrate **102** can be chosen according to need. The insulating substrate **102** can be a square plate, a round plate, or a rectangular plate. In one embodiment, the insulating substrate **102** is a square glass plate, wherein the length of side of the square glass plate is about 10 millimeters, the thickness of the square glass plate is about 1 millimeter.

The cathode electrode **104** can be a conductive layer or a conductive plate. The size, shape, and thickness of the cathode electrode **104** can be chosen according to need. The cathode electrode **104** can be made of metal, alloy, conductive slurry, or indium tin oxide (ITO). In one embodiment, the cathode electrode **104** is an aluminum layer with a thickness of about 1 micrometer.

The dielectric layer **108** can be made of resin, glass, ceramic, oxide, photosensitive emulsion, or combination thereof. The oxide can be silicon dioxide, aluminum oxide, or bismuth oxide. The size and shape of the dielectric layer **108** can be chosen according to need. In one embodiment, the dielectric layer **108** is a ring-shaped SU-8 photosensitive emulsion with a thickness of about 100 micrometers. In one embodiment, the first opening **1080** is coaxial with the through-hole **1100**.

The electron extracting electrode **110** can be a layer electrode defining the through-hole **1100** or a plurality of strip-shaped electrodes. There is a distance between two adjacent strip-shaped electrodes. The electron emitter **106** is exposed through the through-hole **1100** or the distance between two adjacent strip-shaped electrodes. The electron extracting electrode **110** can be made of metal, alloy, conductive slurry, carbon nanotube, or ITO. The metal can be copper, aluminum, gold, silver, or iron. A thickness of the electron extracting electrode **110** can be greater than or equal to 10 micrometers. In one embodiment, the thickness of the electron extracting electrode **110** is in a range from about 30 micrometers to about 60 micrometers.

The through-hole **1100** of the electron extracting electrode **110** is shaped as an inverted funnel such that the width thereof is narrowed as it goes apart from the insulating substrate **102** or the cathode electrode **104**. The width of the through-hole **1100** close to the cathode electrode **104** can be in a range from about 80 micrometers to about 1 millimeter. The width of the through-hole **1100** away from the cathode electrode **104** can be in a range from about 10 micrometers to about 1 millimeter. A secondary electron emission layer can be formed on the sidewall of the through-hole **1100** of the electron extracting electrode **110**. When the electrons emitted from the electron emitter **106** pass the dielectric layer **108** and collide against the sidewall of the through-hole **1100**, the secondary electron emission layer emits secondary electrons, thereby increasing the amount of electrons. The secondary electron emission layer can be formed with an oxide, such as magnesium oxide.

A height of the electron emitter **106** gradually reduces from a center of the electron emitter **106** out. The thickness and the size of the electron emitter **106** can be chosen according to need. The shape of the electron emitter **106** is consistent with the shape of the sidewall of the through-hole **1100**.

The electron emitter **106** includes a plurality of sub-electron emitters **1060**, such as carbon nanotubes, carbon nanofibres, or silicon nanowires. Each sub-electron emitter **1060** has an emission end **10602** and a terminal end **10604** opposite to the emission end **10602**. The terminal end **10604** of each sub-electron emitter **1060** electrically connects to the cathode electrode **104**. In one embodiment, the emission end **10602** of each sub-electron emitter **1060** is in the through-hole **1100** of the electron extracting electrode **110**. That is, the height of each sub-electron emitter **1060** is greater than the thickness of the dielectric layer **108**. A connecting line of the emission end **10602** of each sub-electron emitter **1060** is consistent with the shape of the sidewall of the through-hole **1100**.

A shortest distance between the emission end **10602** of each sub-electron emitter **1060** and the sidewall of the through-hole **1100** is substantially equal. The shortest distances between the emission end **10602** of each sub-electron emitter **1060** and the sidewall of the through-hole **1100** can be in a range from about 5 micrometers to about 300 micrometers. A difference between the shortest distances between the emission end **10602** of each sub-electron emitter **1060** and the sidewall of the through-hole **1100** can be in a range from about 0 micrometers to about 100 micrometers. In one embodiment, the shortest distances between the emission end **10602** of each sub-electron emitter **1060** and the sidewall of the through-hole **1100** are equal, and each sub-electron emitter **1060** is substantially perpendicular to the cathode electrode **104**. In one embodiment, the shortest perpendicular distances between the emission end **10602** of each sub-electron emitter **1060** and the sidewall of the through-hole **1100** are equal, and each sub-electron emitter **1060** is substantially perpendicular to the cathode electrode **104**. The shortest perpendicular distances between the emission end **10602** of each sub-electron emitter **1060** and the sidewall of the through-hole **1100** are in a range from about 5 micrometers to about 250 micrometers.

Furthermore, the electron emitter **106** can be coated with a protective layer (not shown) to improve stability and lifespan of the electron emitter **106**. The protective layer can be made of anti-ion bombardment materials such as zirconium carbide, hafnium carbide, and lanthanum hexaborid. The protective layer can be coated on a surface of each sub-electron emitter **1060**.

In one embodiment, the electron emitter **106** is a carbon nanotube array having a hill-like shape, as shown in FIG. **3**. The carbon nanotube array includes a plurality of carbon nanotubes parallel to each other. Each of the plurality of carbon nanotubes extends to the through-hole **1100** of the electron extracting electrode **110**. A diameter of the hill is in the range from 50 micrometers to 80 micrometers. A maximum height of the hill is in the range from 10 micrometers to 20 micrometers. A diameter of each carbon nanotube is in the range from 40 nanometers to 80 nanometers.

The fixing element **112** can be made of insulating material. A thickness of the fixing element **112** can be chosen according to need. The shape of the fixing element **112** is the same as the shape of the dielectric layer **108**. The fixing element **112** defines a second opening **1120** opposite to the first opening **1080**, such that the electron emitter **106** is exposed through the second opening **1120**. In one embodiment, the fixing element **116** is an insulating slurry layer.

Referring to FIG. **4**, a field emission display **10** of one embodiment includes a cathode substrate **12**, an anode substrate **14**, an anode electrode **16**, a fluorescent layer **18**, and the field emission cathode device **100**.

The cathode substrate **12** and the anode substrate **14** are spaced from each other by an insulating supporter **15**. The cathode substrate **12**, the anode substrate **14**, and the insulating supporter **15** form a vacuum space. The field emission cathode device **100**, the anode electrode **16**, and the fluorescent layer **18** are accommodated in the vacuum space. The anode electrode **16** is located on a surface of the anode substrate **14**. The fluorescent layer **18** is located on a surface of the anode electrode **16**. The field emission cathode device **100** is located on a surface of the cathode substrate **12**. There is a distance between the fluorescent layer **18** and the field emission cathode device **100**. In one embodiment, the cathode substrate **12** is the insulating substrate **102**.

The cathode substrate **12** can be made of insulating material. The insulating material can be ceramics, glass, resins, quartz, or polymer. The anode substrate **14** is a transparent plate. The thickness, size and shape of the anode substrate **14** can be selected according to need. In one embodiment, the cathode substrate **12** and the anode substrate **14** are a glass plate. The anode electrode **16** is an ITO film with a thickness of about 100 micrometers. The fluorescent layer **18** can be round. The diameter of the fluorescent layer **18** can be greater than or equal to the inner diameter of the electron emitter **106** and less than or equal to the outer diameter of the electron emitter **106**. In one embodiment, the fluorescent layer **18** is round and has a diameter approximately equal to the outer diameter of the electron emitter **106**.

Referring to FIG. **5**, a THz electromagnetic tube **30** of one embodiment includes a first substrate **302**, a second substrate **304**, a lens **306**, a first grid electrode **310**, a second grid electrode **312**, a reflecting layer **308**, and the field emission cathode device **100**.

The first substrate **302** and the second substrate **304** form a resonator. The lens **306** is located on one end of the resonator to form an output terminal. The field emission cathode device **100** is located on a surface of the second substrate **304** close to the first substrate **302**. The first grid electrode **310** is located on narrowest of the through-hole **1100** of the electron extracting electrode **110**. The first grid electrode **310** covers the through-hole **1100**. The reflecting layer **308** is located on a surface of the first substrate **302** close to the second substrate **304** to reflect electrons. The reflecting layer **308** is opposite to the field emission cathode device **100**. The second grid electrode **312** is suspended between the first grid electrode **310** and the reflecting layer **308**. The electrons extracted from the electron emitter **106** of the field emission cathode device **100** are reflected by the reflecting layer **308** and oscillated in the resonator. The electrons are finally exported through the output terminal.

The first substrate **302** and the second substrate **304** can be made of metal, polymer or silicon. In one embodiment, the first substrate **302** and the second substrate **304** are made of silicon.

The first grid electrode **310** and the second grid electrode **312** can be a plane structure having a plurality of meshes. The shape of the plurality of meshes can be chosen according to need. An area of each of the plurality of meshes can be in a range from about 1 square micron to about 800 square microns, such as about 10 square microns, about 50 square microns, about 100 square microns, about 150 square microns, about 200 square microns, about 250 square microns, about 350 square microns, about 450 square microns, and about 600 square microns. The first grid electrode **310** and the second grid electrode **312** can be made of metal, alloy, conductive slurry, carbon nanotube, or ITO. The metal can be copper, aluminum, gold, silver, or iron. In one embodiment, the first grid electrode **310** and the second grid electrode **312** are made of at least two stacked carbon nanotube films. The carbon nanotube film includes a plurality of successive and oriented carbon nanotubes joined end-to-end by van der Waals attractive force therebetween. An angle between the aligned directions of the carbon nanotubes in two adjacent carbon nanotube films can be in a range from about 0 degrees to about 90 degrees. The area of each mesh of the first grid electrode **310** and the area of each mesh of the second grid electrode **312** are approximately equal, and the area of each mesh is in a range from about 10 micrometers to about 100 micrometers.

Referring to FIG. **6**, an embodiment of a field emission cathode device **200** is shown where the electron emitter **106** is a carbon nanotube linear structure including a plurality of carbon nanotubes.

The carbon nanotube linear structure includes a plurality of carbon nanotube wires substantially parallel with each other or a plurality of carbon nanotube wires twisted with each other. That is, the carbon nanotube wire can be twisted or untwisted. The twisted carbon nanotube wire can be formed by twisting a drawn carbon nanotube film using a mechanical force to turn the two ends of the drawn carbon nanotube film in opposite directions. Each carbon nanotube wire includes a plurality of carbon nanotubes helically oriented around an axial direction of the carbon nanotube wire. Therefore, the carbon nanotube wire has a larger mechanical strength.

The untwisted carbon nanotube wire can be obtained by treating the drawn carbon nanotube film drawn from the carbon nanotube array with the volatile organic solvent. Each carbon nanotube wire includes a plurality of carbon nanotubes parallel to the axial direction of the carbon nanotube wire.

The carbon nanotube linear structure includes a first end and a second end opposite to the first end. The first end of the carbon nanotube linear structure is electrically connected to the cathode electrode **104**. The second end of the carbon nanotube linear structure includes a plurality of taper-shape structures, as shown in FIGS. **7** and **8**. The plurality of taper-shape structures includes a plurality of carbon nanotubes oriented substantially along an axial direction of the taper-shape structures. The carbon nanotubes are substantially parallel to each other, and are combined with each other by van der Waals attractive force.

The plurality of taper-shape structures includes one carbon nanotube close to the narrowest of the through-hole **1100** than the other adjacent carbon nanotubes, and the carbon nanotube can emit more electrons. The carbon nanotube close to narrowest of the through-hole **1100** than the other adjacent carbon nanotubes is fixed with the other adjacent carbon nanotubes by van der Waals attractive force. Therefore, the carbon nanotube can bear large working voltage. Additionally, there can be a gap between tops of the two adjacent taper-shape structures. That can prevent the shield effect caused by the adjacent taper-shape structures.

An envelope curve of the second end of the carbon nanotube linear structure is consistent with the shape of the sidewall of the through-hole **1100**. A shortest distance between one end of the carbon nanotube linear structure away from the cathode electrode **104** and the sidewall of the through-hole **1100** is substantially equal. A shortest distance between the tops of the taper-shape structures and the sidewall of the through-hole **1100** is substantially equal, wherein the shortest distance can be in a range from about 5 micrometers to about 300 micrometers. In one embodiment, the shortest distances between the tops of the taper-shape structures and the sidewall of the through-hole **1100** are equal. In one embodiment, the shortest perpendicular distances between the tops of the taper-shape structures and the sidewall of the through-hole **1100** are approximately equal. A difference between the shortest distances between the tops of the taper-shape structures and the sidewall of the through-hole **1100** can be in a range from about 0 micrometers to about 100 micrometers.

Referring to FIG. **9**, an embodiment of a field emission display **20** is shown where the electron emitter **106** is the carbon nanotube linear structure including the plurality of carbon nanotubes.

Referring to FIG. **10**, an embodiment of a THz electromagnetic tube **40** is shown where the electron emitter **106** is the carbon nanotube linear structure including the plurality of carbon nanotubes.

Referring to FIG. **11**, an embodiment of a field emission cathode device **300** is shown where the electron emitter **106** includes an electric conductor **114** and a plurality of sub-electron emitters **1060**. The shape of the electric conductor **114** is a triangle having a first surface **1142**, a second surface **1144**, and a third surface. The third surface of the electric conductor **114** is electrically connected to the cathode electrode **104**. The plurality of sub-electron emitters **1060** is located on the first surface **1142** and the second surface **1144**. The plurality of sub-electron emitters **1060** is electrically connected to the first surface **1142** and the second surface **1144**. The electric conductor **114** can be made of conducting material, such as metal, conducting polymer.

Referring to FIG. **12**, an embodiment of a field emission cathode device **400** is shown where the electron emitter **106** includes an electric conductor **214** and a plurality of sub-electron emitters **1060**. The shape of the electric conductor **214** is a hemisphere having a fourth surface **2142** and a fifth surface. The fourth surface **2142** is an arc winding to the cathode electrode **104**. The plurality of sub-electron emitters **1060** is located on the fourth surface **2142** and electrically connected to the fourth surface **2142**. The shape of the fifth surface is plane. The fifth surface is electrically connected to the cathode electrode **104**. The electric conductor **214** can be made of conducting material, such as metal, conducting polymer. The plurality of sub-electron emitters **1060** can have equal lengths.

It is to be understood the shape of the electric conductors **114** or **214** is consistent with the shape of the sidewall of the through-hole **1100**.

In summary, the shortest distance between each of the plurality of sub-electron emitters **1060** and the sidewall of the through-hole **1100** is substantially equal, such that the electric field of each of the plurality of sub-electron emitters **1060** is substantially equal, improving the emission current destiny of the electron emitter **106**. Furthermore, the electron emitter **106** has a height gradually reducing from a center of the electron emitter **106** out, or is a carbon nanotube linear structure including at least one taper-shape structure. Therefore, the shield effect caused by adjacent sub-electron emitters **1060** can be prevented, improving the emission current destiny of the electron emitter **106**. Moreover, the through-hole **1100** of the electron extracting electrode **110** is shaped as an inverted funnel such that the width thereof is narrowed away from the insulating substrate **102**. That can focus the electron beam extracted from the electron emitter **106**, further improving the emission current destiny of the electron emitter **106**.

It is to be understood that the above-described embodiment is intended to illustrate rather than limit the disclosure. Variations may be made to the embodiment without departing from the spirit of the disclosure as claimed. The above-described embodiments are intended to illustrate the scope of the disclosure and not restricted to the scope of the disclosure.

It is also to be understood that the above description and the claims drawn to a method may include some indication in reference to certain steps. However, the indication used is only to be viewed for identification purposes and not as a suggestion as to an order for the steps.

What is claimed is:

1. A field emission cathode device, comprising:

a cathode electrode having a planar surface;

an electron emitter located on the planar surface of the cathode electrode and electrically connected to the cathode electrode, wherein the electron emitter comprises a plurality of sub-electron emitters, a height of the electron emitter gradually reduces from a center of the electron emitter out to each of edge of the electron emitter; and a connecting line of the end of each of the plurality of sub-electron emitters, away from the cathode electrode, is consistent with the shape of the sidewall of the through-hole;

an electron extracting electrode spaced from the cathode electrode by a dielectric layer, wherein the electron extracting electrode defines a through-hole, and a part of the plurality of sub-electron emitters extends to the through-hole;

wherein the distances between an end of each of the plurality of sub-electron emitters away from the cathode electrode and the closest portion of a sidewall of the through-hole are substantially equal.

2. The field emission cathode device of claim **1**, wherein the distance is in a range from about 5 micrometers to about 300 micrometers.

3. The field emission cathode device of claim **1**, wherein the through-hole is shaped as an inverted funnel such that the width thereof is narrowed as it goes apart from the cathode electrode.

4. The field emission cathode device of claim **1**, wherein a secondary electron emission layer is formed on the sidewall of the through-hole of the electron extracting electrode.

5. The field emission cathode device of claim **1**, wherein a height of each of the plurality of sub-electron emitters is greater than a thickness of the dielectric layer.

6. The field emission cathode device of claim **1**, wherein the electron emitter is a carbon nanotube array comprising a plurality of carbon nanotubes substantially parallel to each other, and the plurality of sub-electron emitters is the plurality of carbon nanotubes.

7. The field emission cathode device of claim **6**, wherein each of the plurality of carbon nanotubes extends towards the through-hole of the electron extracting electrode.

8. The field emission cathode device of claim **1**, wherein the plurality of sub-electron emitters are carbon nanotubes, carbon nanofibres, or silicon nanowires.

9. The field emission cathode device of claim **1**, wherein the electron emitter is a carbon nanotube linear structure comprising a plurality of carbon nanotubes, and each of the plurality of carbon nanotubes functions as each of the plurality of sub-electron emitters, and one end of the carbon nanotube linear structure away from the cathode electrode comprises a plurality of taper-shape structures.

10. The field emission cathode device of claim **9**, the through-hole comprises a first opening and a second opening opposite to the first opening, and the plurality of taper-shape structures comprises one carbon nanotube which is closer to the first opening of the through-hole than other adjacent carbon nanotubes, wherein an area of the first opening is less than an area of the second opening.

11. The field emission cathode device of claim **10**, the one carbon nanotube closest to the first opening of the through-hole is fixed with the other adjacent carbon nanotubes by van der Waals attractive force.

12. The field emission cathode device of claim **1**, further comprising a fixing element located on a surface of the electron extracting electrode.

13. The field emission cathode device of claim **1**, wherein the electron emitter comprises an electric conductor having a shape consistent with the shape of the sidewall of the through-hole.

14. A field emission equipment, comprising:

a cathode electrode having a planar surface;

an electron emitter located on the planar surface of the cathode electrode and electrically connected to the cathode electrode, wherein the electron emitter comprises a plurality of sub-electron emitters, a height of the electron emitter gradually reduces from a center of the electron emitter out to each of edge of the electron emitter; and a connecting line of the end of each of the plurality of sub-electron emitters, away from the cathode electrode, is consistent with the shape of the sidewall of the through-hole;

an electron extracting electrode spaced from the cathode electrode by a dielectric layer, wherein the electron extracting electrode defines a through-hole, and a part of the plurality of sub-electron emitters extends to the through-hole, a connecting line of an end of each of the plurality of sub-electron emitters away from the cathode electrode is consistent with the shape of a sidewall of the through-hole; and

an anode electrode having a fluorescent layer located on a surface of the anode electrode, wherein the electron extracting electrode is located between the cathode electrode and the anode electrode.

15. The field emission cathode device of claim **14**, wherein the through-hole is shaped as an inverted funnel such that the width thereof narrows away from the cathode electrode.

16. The field emission cathode device of claim **14**, wherein a distance between the end of each of the plurality of sub-electron emitters away from the cathode electrode and the sidewall of the through-hole is in a range from about 5 micrometers to about 300 micrometers.

17. A field emission equipment, comprising:

a cathode electrode having a planar surface;

an electron emitter located on the planar surface of the cathode electrode and electrically connected to the cathode electrode, wherein the electron emitter comprises a plurality of sub-electron emitters, a height of the electron emitter gradually reduces from a center of the electron emitter out to each of edge of the electron emitter; and a connecting line of the end of each of the plurality of sub-electron emitters, away from the cathode electrode, is consistent with the shape of the sidewall of the through-hole;

an electron extracting electrode spaced from the cathode electrode by a dielectric layer, wherein the electron extracting electrode defines a through-hole, and a part of the plurality of sub-electron emitters extends to the through-hole, distances between an end of each of the plurality of sub-electron emitters away from the cathode electrode and the closest portion of a sidewall of the through-hole are substantially equal;

a first substrate and a second substrate formed a resonator; and

a lens located on one end of the resonator to form an output terminal, wherein electrons extracted from the electron emitter are oscillated in the resonator and exported through the output terminal.

18. The field emission cathode device of claim **17**, wherein the electron emitter is a carbon nanotube array comprising a plurality of carbon nanotubes substantially parallel to each other, and the plurality of sub-electron emitters is the plurality of carbon nanotubes.

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